Irrigation Scheduling

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What is Irrigation Scheduling?

- Programming the timing and amount of water applied on a crop.
- Based on:
  - Soil water content and soil capacity to store water.
  - Evapotranspiration rate of the crop at its' current crop growth and tolerance to deficit.
  - Irrigation System capacity and efficiency.

Principles of Scheduling

Understand your SOIL

Texture/Profile

Available Water Holding Capacity (AWHC)

Know your CROP

Daily Evapotranspiration

Effective rooting depth

Growth Stage

Ability to withstand water deficit

Update your IRRIGATION SYSTEM

Percent Chart current and correct

- Pressure
- Flow
- End tower speed

Center Pivot Focus, but principles apply to Furrow, Sideroll, Flood and others

Soil Water Terminology

Saturation Water: is the soil water content where all soil pores are filled (Saturation) and is the water that readily percolates or drains out from the root zone by gravity

Field Capacity (FC): is the amount of water that remains in the soil after all the Saturation Water. Reached in roughly 24 hours in sandy soil, and up to 3 days in heavier (higher clay and organic matter). (Measured in the lab at 0.1 to 0.33 bars)

"Permanent Wilting Point" (PWP): When plants take up all the **Available Water** for a given soil, soil cannot supply any water to keep plants from dying. (Lab measure is at -15 bars)

Available Water Holding Capacity (AWHC or AWC): is the water held between field capacity and permanent wilting point.

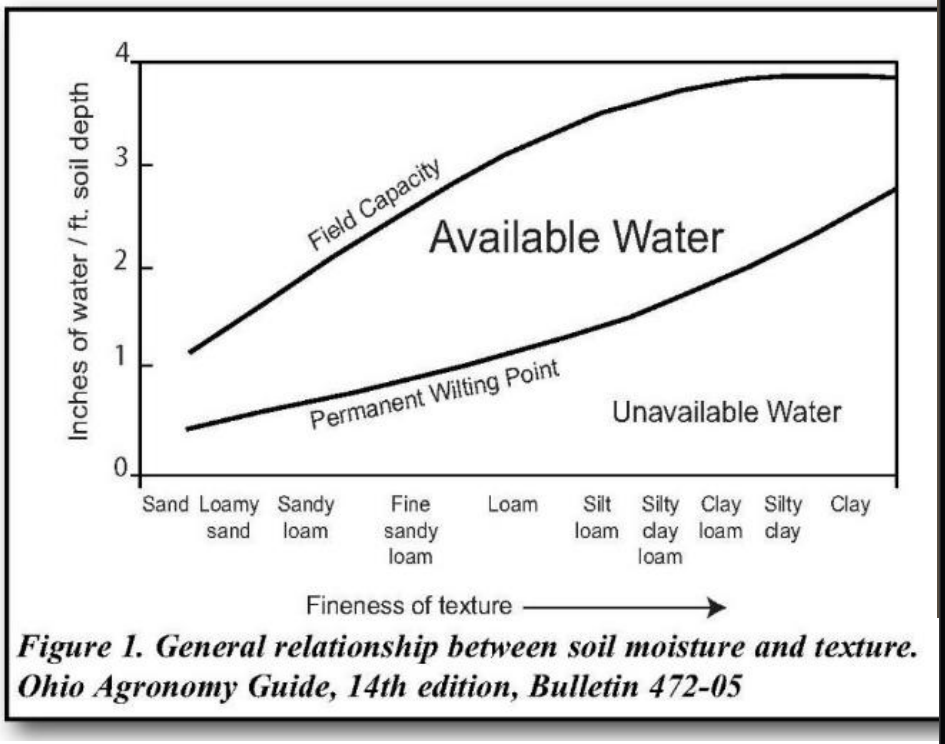
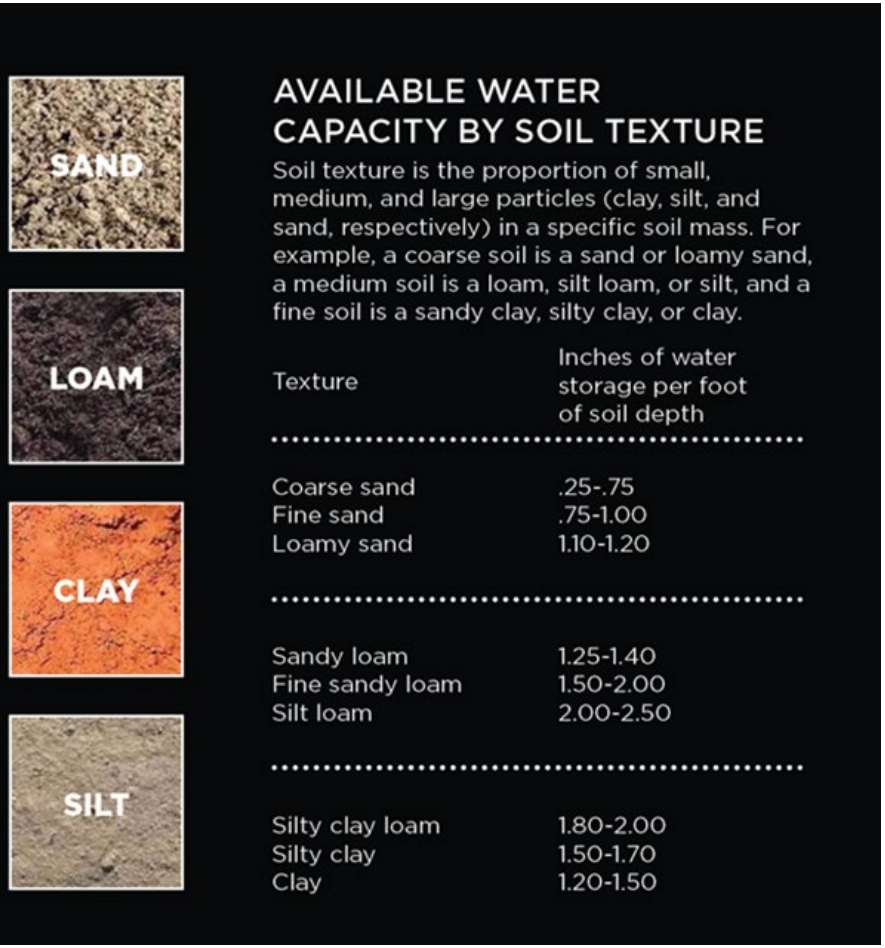


Figure 1. General relationship between soil moisture and texture.
Ohio Agronomy Guide, 14th edition, Bulletin 472-05



AWHC and Texture

Dynamic AWHC

Soil Organic Matter 

Compaction 

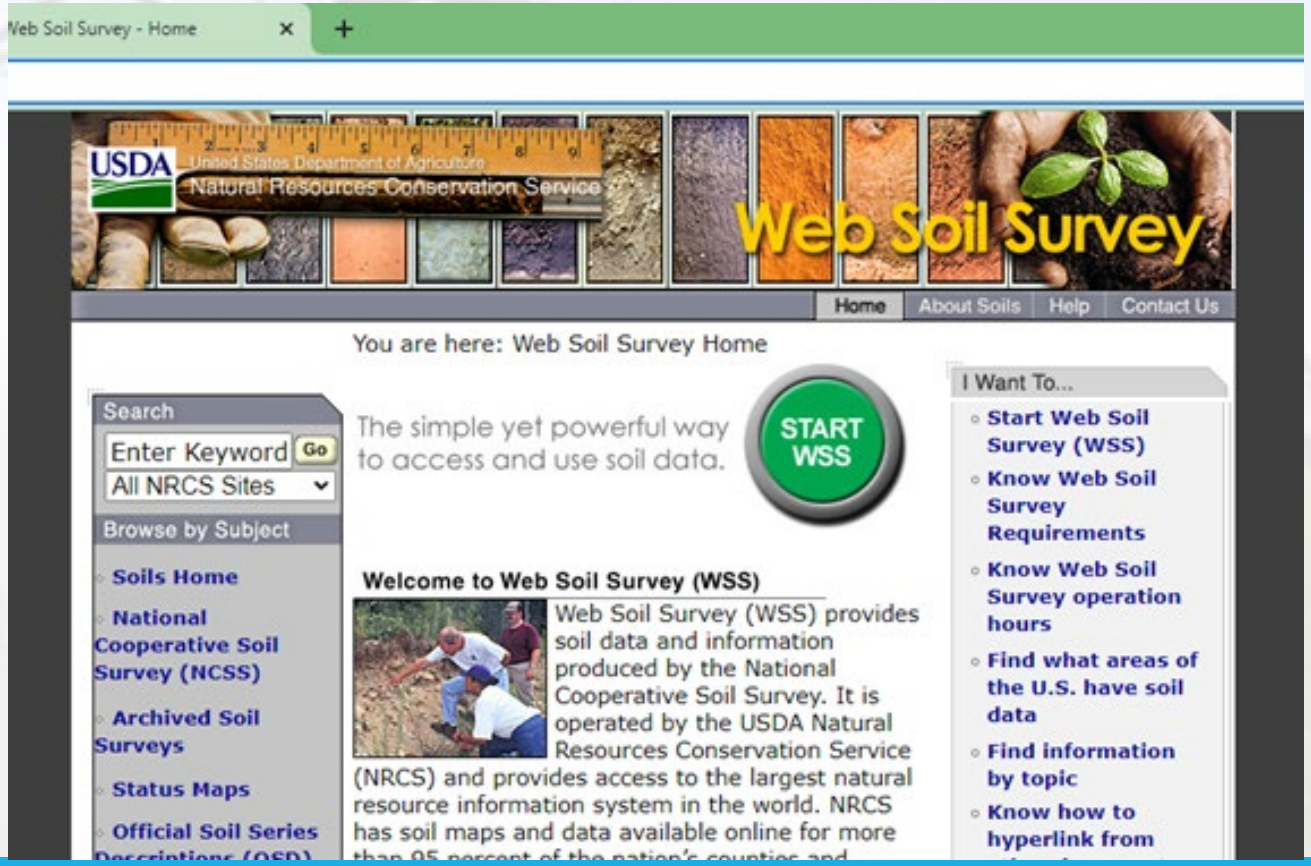
Salinity/Sodium affected soils 

The Benefits of Higher Organic Matter

- According to most research, a 0.1% increase in organic matter typically results in a roughly 0.15% increase in available water in soils
- 1% increase in organic matter, you can expect around a 1.5% increase in available water capacity in the soil. https://csanr.wsu.edu/putting-numbers-to-the-difficult-task-of-increasing-soil-organic-matter/
- Every 1% increase in organic matter results in as much as 25,000 gallons of available soil water per acre.
- Each pound of soil organic matter (SOM) can hold up to 18 to 20 pounds of water and 1% of SOM can hold up to 1 inch of water in the soil. https://csanr.wsu.edu/putting-numbers-to-the-difficult-task-of-increasing-soil-organic-matter/

Web Soil Survey (WSS)

https://websoilsurvey.nrcs.usda.gov/app/



Calculating Available Water for a given crop

AW = Root Depth (inches) X AWHC (in/in)

AWHC was just explored through Web Soil Survey

What do I need to Know to Schedule Irrigations

1. **Management Allowed Deficit: MAD for my crop's growth stage**
2. ET for the time period under consideration

   Sources:
   - www.coagmet.colostate.edu
   - Agro Engineering
   - Open ET
3. Soil Moisture Status at this moment
4. System characteristics, Efficiencies

Management Allowed Deficit-MAD

- MAD = The portion of the water that a crop plant can extract from the soil without causing more than acceptable harm (Yield and/or Quality)
- MAD depends on: Soil type, Crop, Stage of growth

Available Water(AW) = AVAILABLE WATER CAPACITY x ROOTING DEPTH

MAD = % allowable deficit x AW

- Alfalfa: 50%
- Potatoes and vegetable crops: 25-35%
- Small grains: Early boot to flag: 50%, flag to early fill: 40%, Late: 60%
- Sorghum, Millet, Sorghum Sudan and C4 Grasses: 50-60%
- Corn: 50% except 40% during tasseling
- Soybeans, Dry Beans: 40 to 50% except 35-40% during flowering
- Irrigated pasture: 50-60%

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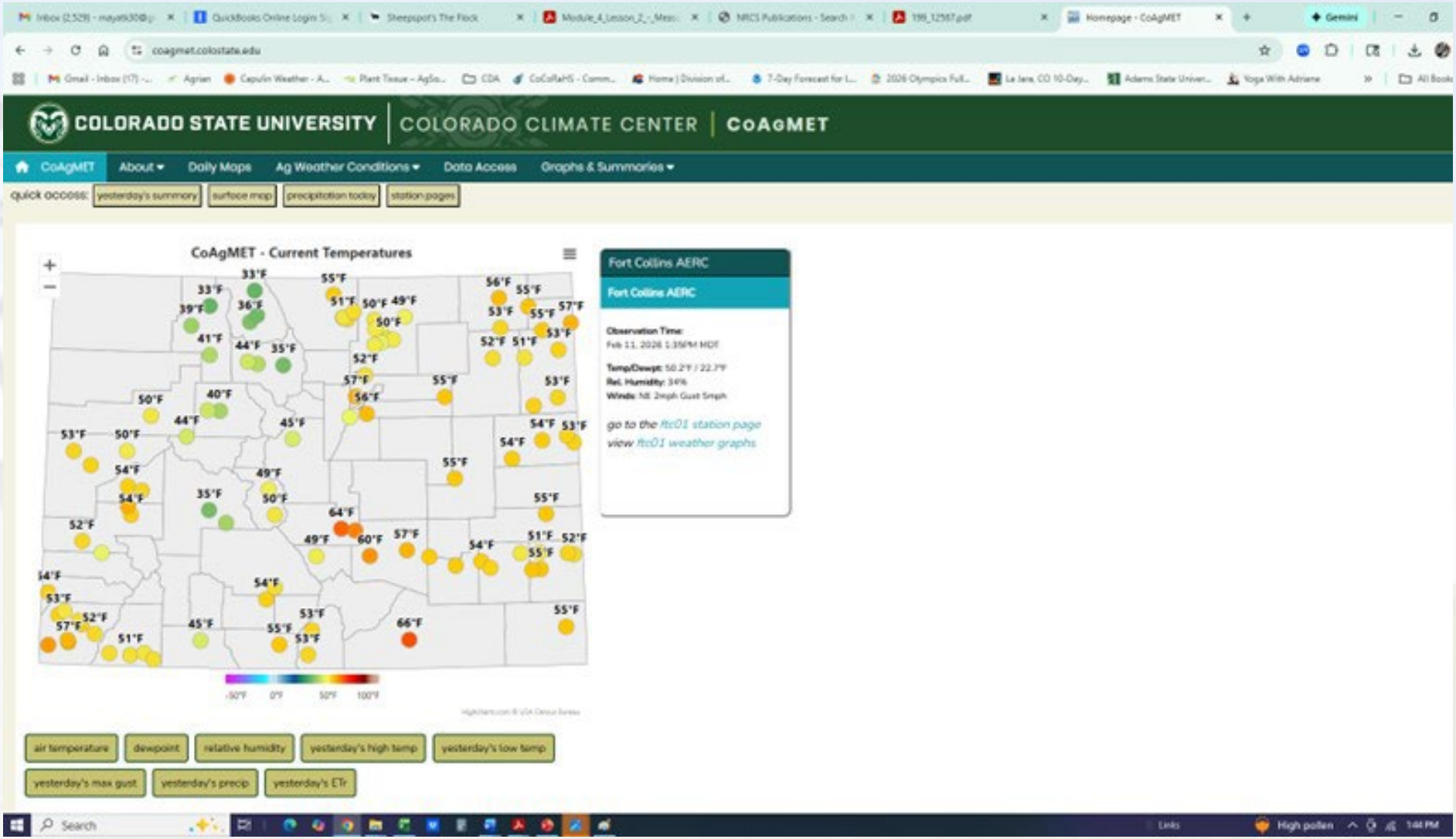
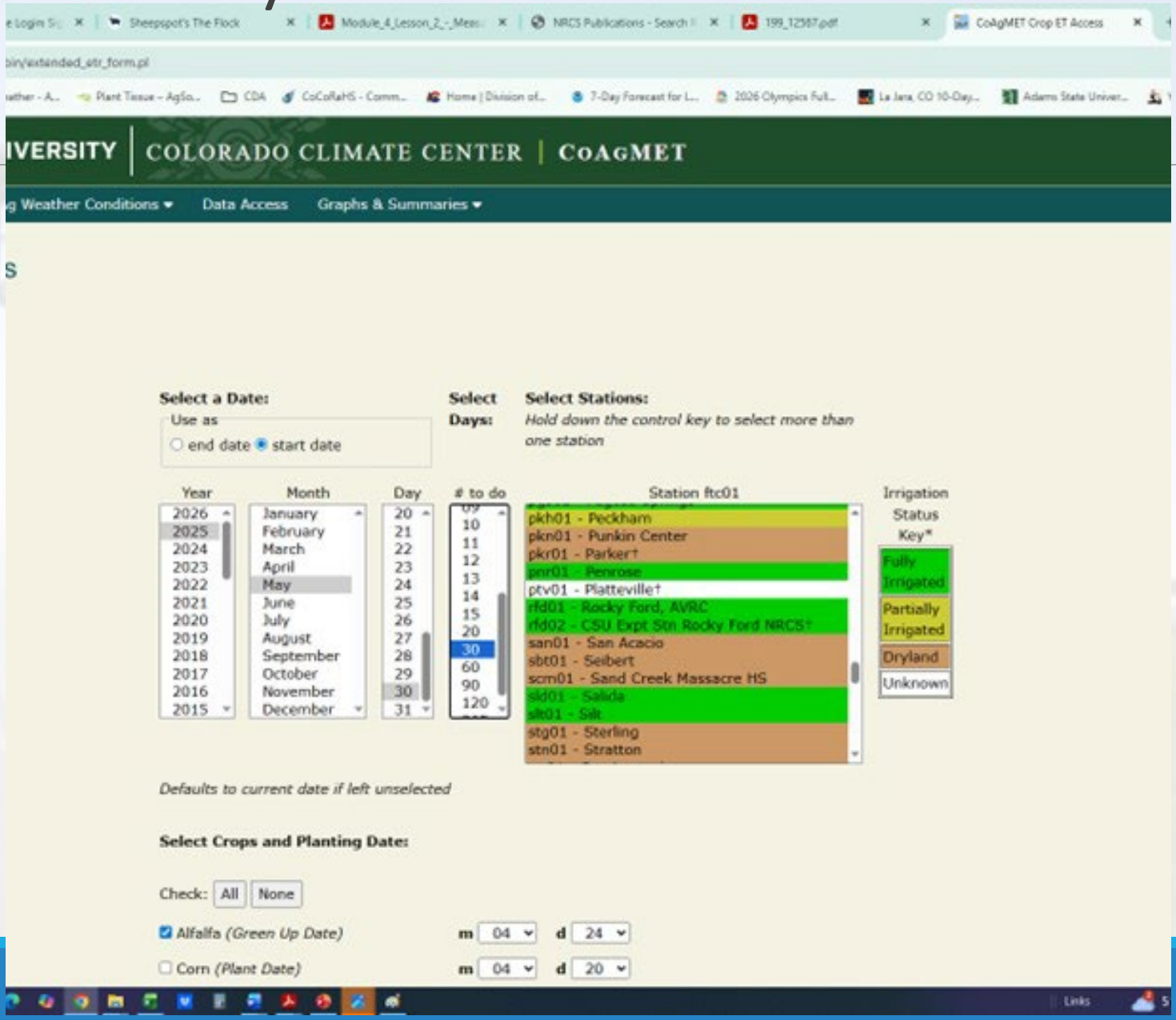
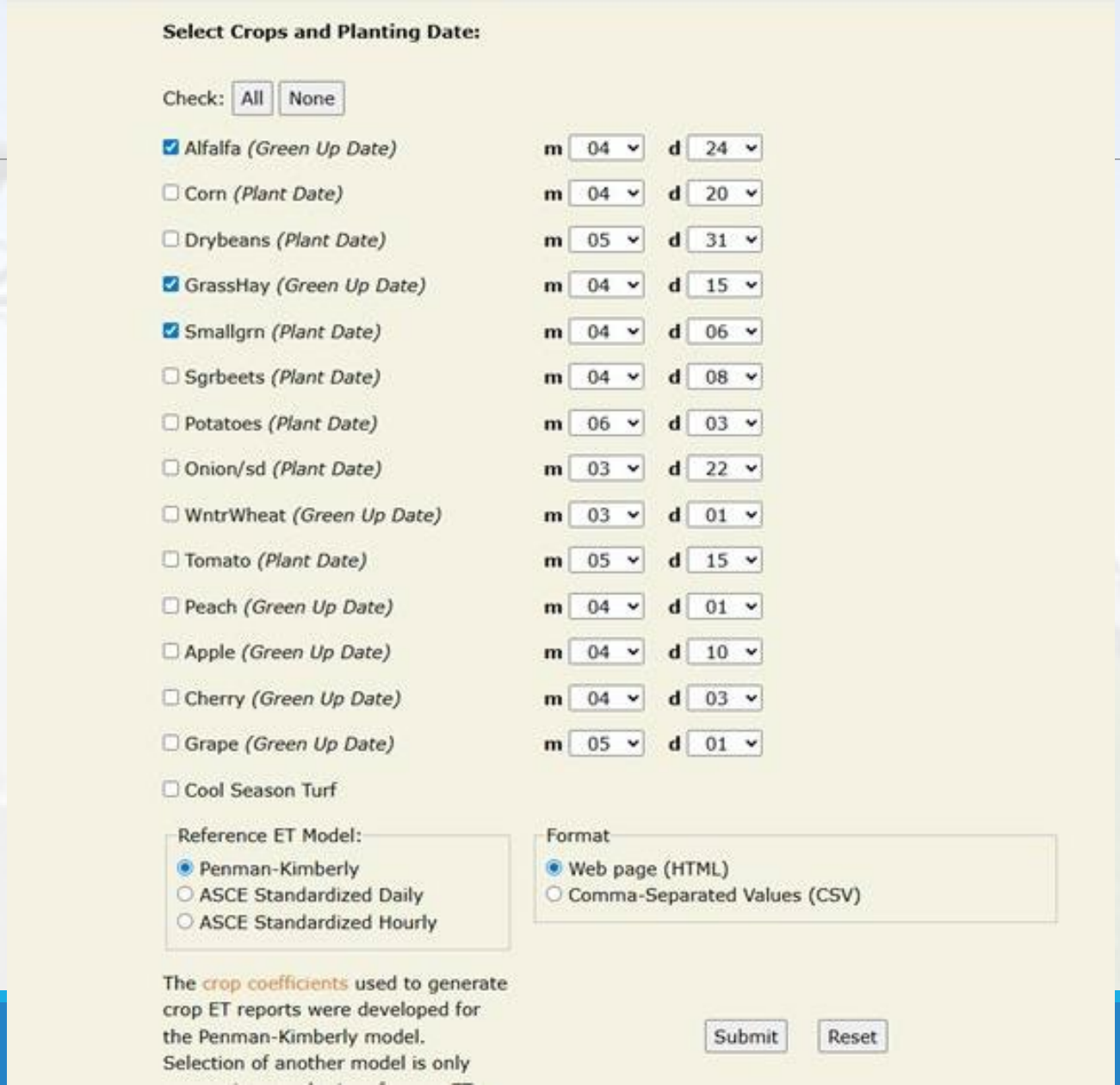
Using CoAgMet: https://coagmet.colostate.edu/



Select your dates and Stations



Select your crops and enter plant and green-up dates



Select Crops and Planting Date:

Check: All None

☑ Alfalfa *(Green Up Date)*	m 04	d 24
☐ Corn *(Plant Date)*	m 04	d 20
☐ Drybeans *(Plant Date)*	m 05	d 31
☑ GrassHay *(Green Up Date)*	m 04	d 15
☑ Smallgrn *(Plant Date)*	m 04	d 06
☐ Sgrbeets *(Plant Date)*	m 04	d 08
☐ Potatoes *(Plant Date)*	m 06	d 03
☐ Onion/sd *(Plant Date)*	m 03	d 22
☐ WntrWheat *(Green Up Date)*	m 03	d 01
☐ Tomato *(Plant Date)*	m 05	d 15
☐ Peach *(Green Up Date)*	m 04	d 01
☐ Apple *(Green Up Date)*	m 04	d 10
☐ Cherry *(Green Up Date)*	m 04	d 03
☐ Grape *(Green Up Date)*	m 05	d 01
☐ Cool Season Turf		

Reference ET Model:
- ◉ Penman-Kimberly
- ○ ASCE Standardized Daily
- ○ ASCE Standardized Hourly

Format
- ◉ Web page (HTML)
- ○ Comma-Separated Values (CSV)

The crop coefficients used to generate crop ET reports were developed for the Penman-Kimberly model. Selection of another model is only

Submit Reset

Crop Growth Stage

Built in to CoAgMet somewhat = “Crop Coefficients”

Field verification involves estimating the percent cover

Percent cover X Potential ET = Actual ET for that growth stage

Many crops, particularly corn, beans, and small grains DO NOT LIKE early overwatering!

What factors affect ET

1. Solar Radiation: Energy from the sun
2. Temperature
3. Wind
4. Humidity
5. Crop
6. Stage of Growth: Crop Coefficients
7. Soil moisture and salinity
8. Stand density, plant nutrition, crop variety etc.

Week of July 1 to July 10							
Date	Alfalfa	GrassHay	Smallgrn	Potatoes	ETr	ETo	Precip
7/1/2023	0.31	0.27	0.26	0.27	0.31	0.24	0
7/2/2023	0.27	0.24	0.22	0.24	0.27	0.22	0
7/3/2023	0.31	0.27	0.25	0.28	0.31	0.25	0
7/4/2023	0.28	0.25	0.22	0.25	0.28	0.23	0
7/5/2023	0.3	0.26	0.23	0.27	0.3	0.24	0
7/6/2023	0.39	0.34	0.28	0.35	0.39	0.3	0
7/7/2023	0.39	0.34	0.27	0.35	0.39	0.3	0
7/8/2023	0.39	0.34	0.25	0.35	0.39	0.3	0
7/9/2023	0.31	0.27	0.19	0.28	0.31	0.24	0
7/10/2023	0.27	0.23	0.16	0.24	0.27	0.22	0

How weather affects ET

		T Max	T Min	Wind Run	Precip	Wind Gusts	Ref ET
Month	Day	^{0}F	^{0}F	Mi/Day	In	mph	ASCE
7	1	81.4	41.5	126.6	0	7.8	0.30
7	2	80.2	47.2	146.5	0	20.7	0.28
7	3	84.2	44.2	130.9	0	9.0	0.31
7	4	82.7	48.2	154.3	0	16	0.29
7	5	84.4	46.2	249.6	0	20	0.34
7	6	83.0	41.7	264.7	0	17.2	0.40
7	7	85.2	45.1	232	0	18.2	0.39
7	8	84.9	45.2	258.8	0	18.0	0.40
7	9	86.2	43.9	123.2	0	8.2	0.30
7	10	81.8	49.8	152.7	0	11.8	0.28

Adjustments

Hot and Windy—Use Max ET numbers

Cloudy afternoon: Use 2/3 of Max ET

Cloudy all day: Use ½ of Max ET

But remember you can always get info off the web for ET from CoAgMet stations

And always check you soils: Auger, shovel, sensors

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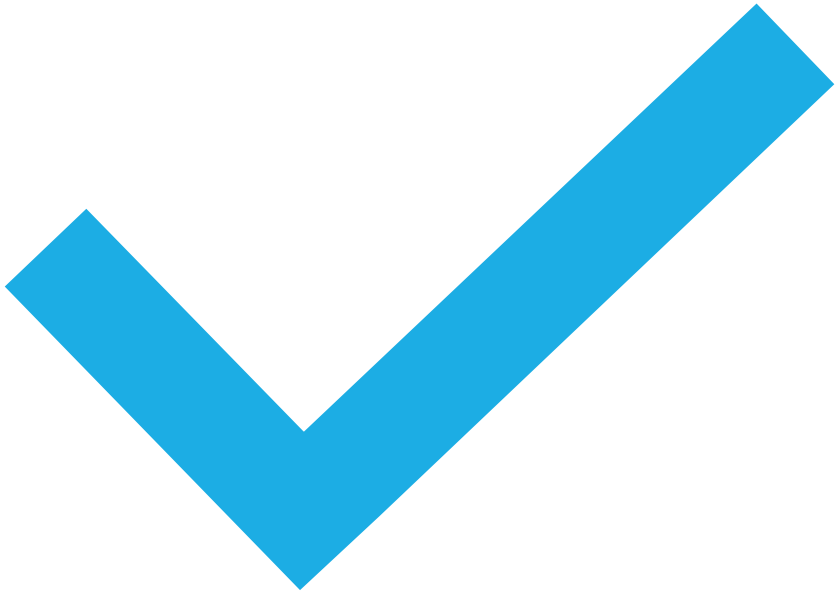
4. System characteristics, Efficiencies



Verifying Moisture

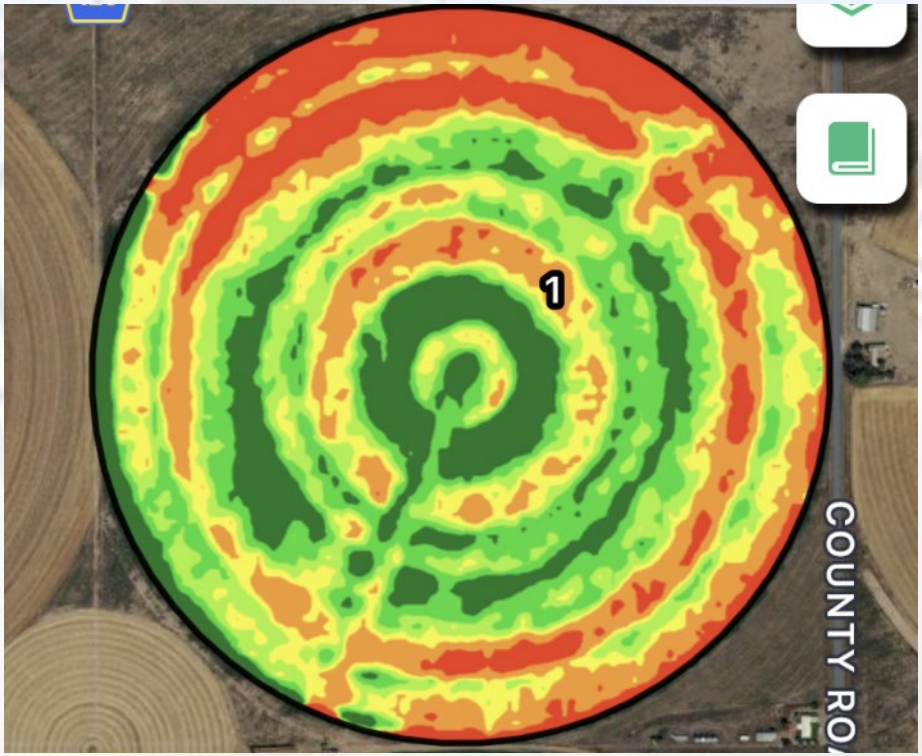
- Shovel, Auger, field check
  - Using the “Feel Method”
- Moisture Sensors
  - Tensiometers or Gypsum Blocks
  - Capacitance probes
  - Autonomous Pivot


TACOMA

Oakfield Apparatus Augers

AMS Sampling Equipment

Positioning Moisture Sensors



- Original software recommended placing sensors based on soil type
- I recommend the start position, outer 2 spans
- Position sensors away where the nozzle spray will reach them when the system starts
- **If you have nozzling issues, sensors may be inaccurate**

Feel Method

https://nrcspad.sc.egov.usda.gov/DistributionCenter/

Appearance of fine sand and loamy fine sand soils at various soil moisture conditions.

Available Water Capacity 0.6-1.2 inches/foot

Percent Available: Currently available soil moisture as a percent of available water capacity.

In/ft. Depleted: Inches of water currently needed to refill a foot of soil to field capacity.

0-25 percent available
1.2-0.5 in./ft. depleted

Dry, loose, will hold together if not disturbed, loose sand grains on fingers with applied pressure. (Not pictured)

25-50 percent available
0.9-0.3 in./ft. depleted

Slightly moist, forms a very weak ball with well-defined finger mark

50-75 percent available
0.6-0.2 in./ft. depleted

Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, moderate water staining on fingers, will not ribbon.

75-100 percent available
0.3-0.0 in./ft. depleted

Wet, forms a weak ball, loose and aggregated sand grains remain on fingers, darkened color, heavy water staining on fingers, will not ribbon

100 percent available
0.0 in./ft. depleted (field capacity)

Wet, forms a weak ball, moderate to heavy soil/water coating on fingers, wet outline of soft ball remains on hand. (Not pictured)

Feel Method

	Coarse Texture–Fine Sand and Loamy Fine Sand	Moderately Coarse Texture–Sandy Loam and Fine Sandy Loam	Medium Texture–Sandy Clay Loam, Loam, and Silt Loam	Fine Texture–Clay, Clay Loam, or Silty Clay Loam
Available Water Capacity (Inches/Foot)				
	0.6-1.2	1.3-1.7	1.5-2.1	1.6-2.4
Available Soil Moisture Percent	Soil Moisture Deficit (SMD) in inches per foot when the feel and appearance of the soil are as described.			
0-25	Dry, loose, will hold together if not disturbed, loose sand grains on fingers with applied pressure. SMD 1.2 - 0.5	Dry, forms a very weak ball,[1] aggregated soil grains break away easily from ball. SMD 1.7 - 1.0	Dry, soil aggregations break away easily, no moisture staining on fingers, clods crumble with applied pressure. SMD 2.1 - 1.1	Dry, soil aggregations easily separate, clods are hard to crumble with applied pressure. SMD 2.4 - 1.2
25-50	Slightly moist, forms a very weak ball with well-defined finger marks, light coating of loose and aggregated sand grains remain on fingers. SMD 0.9 - 0.3	Slightly moist, forms a weak ball with defined finger marks, darkened color, no water staining on fingers, grains break away. SMD 1.3 - 0.7	Slightly moist, forms a weak ball with rough surfaces, no water staining on fingers, few aggregated soil grains break away. SMD 1.6 - 0.8	Slightly moist, forms a weak ball, very few soil aggregations break away, no water stains, clods flatten with applied pressure. SMD 1.8 - 0.8
50-75	Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, moderate water staining on fingers, will not ribbon.[2] SMD 0.6 - 0.2	Moist, forms a ball with defined finger marks, very light soil/water staining on fingers, darkened color, will not slick. SMD 0.9 - 0.3	Moist, forms a ball, very light water staining on fingers, darkened color, pliable, forms a weak ribbon between thumb and forefinger. SMD 1.1- 0.4	Moist, forms a smooth ball with defined finger marks, light soil/water staining on fingers, ribbons between thumb and forefinger. SMD 1.2 - 0.4
75-100	Wet, forms a weak ball, loose and aggregated sand grains remain on fingers, darkened color, heavy water staining on fingers, will not ribbon. SMD 0.3 - 0.0	Wet, forms a ball with wet outline left on hand, light to medium water staining on fingers, makes a weak ribbon between thumb and forefinger. SMD 0.4 - 0.0	Wet, forms a ball with well defined finger marks, light to heavy soil/water coating on fingers, ribbons between thumb and forefinger. SMD 0.5 - 0.0	Wet, forms a ball, uneven medium to heavy soil/water coating on fingers, ribbons easily between thumb and forefinger. SMD 0.6 - 0.0
Field Capacity (100 percent)	Wet, forms a weak ball, moderate to heavy soil/water coating on fingers, wet outline of soft ball remains on hand. SMD 0.0	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, medium to heavy soil/water coating on fingers. SMD 0.0	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, medium to heavy soil/water coating on fingers. SMD 0.0	Wet, forms a soft ball, free water appears on soil surface after squeezing or shaking, thick soil/water coating on fingers, slick and sticky. SMD 0.0

So… where do I check?

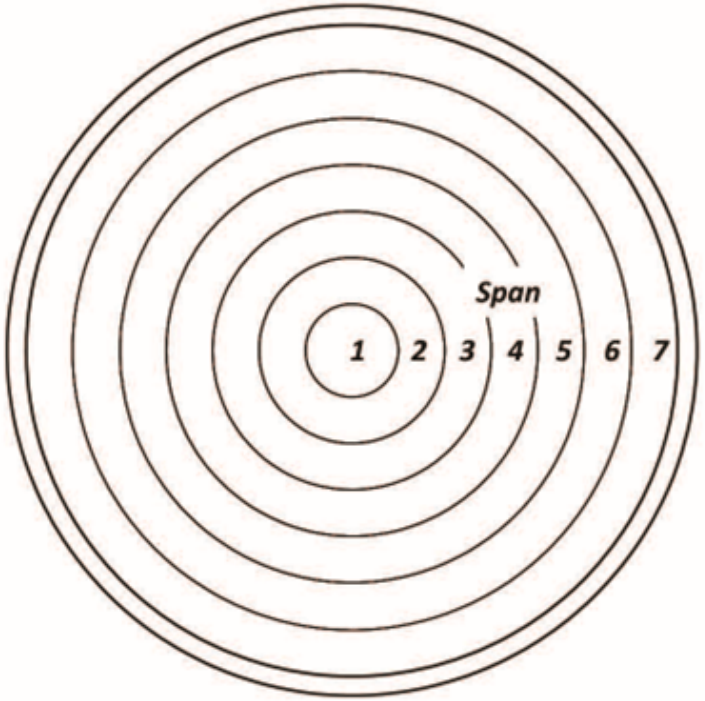
At the Start Position

In Front of the sprinkler

If you have concerns, at the stop position

On a sprinkler: Outer 2, maybe 3 spans

So… where do I check?



Span	Span end, ft	Area within the span, acres	Discharge from span gpm
1	180	2	14
2	360	7	42
3	549	12	71
4	720	16	99
5	900	21	127
6	1080	26	156
7	1269	39	184
O. Hang	1310	9	56
Total		124	750

Figure L-1. Characteristics of a typical center pivot. (Note that 45% of the land area is under the outer two spans while only about 7% of the land is under the first two spans.)

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Irrigation Efficiencies

Defined as the Percent of the water applied in an irrigation that goes to crop evapotranspiration

Sprinklers: 80% to 95%

- Depends on nozzling, height, runoff

Sideroll: 60 to 85%

Surface/Flood: 35% to 60%

Wild Flood/Meadows: Depends on water distribution

For Sprinklers and Sideroll: Current Percent vs. Depth Chart?

- Correct Flow?
  - Design Flow is often NOT the actual
  - Nozzle charts are often based on un-tested flow and pressure
- Correct Pressure?
  - Well Problems/declining water will manifest here!!!
  - Pattern problems
  - Biggest impact will be on the outer 2 to 3 spans
- Center Drive Changes?
  - Gearbox went out, center drive replaced with something off an old sprinkle or the shelf in the shop?
  - Ground was rented out (carrots and lettuce growers will put in super fast gearboxes)

John Smith XYZ

Irrigation Depth Chart

7-Jul-23

DEPTH (in)	TRUE PERCENT (%)	DIAL SETTING (%)	HOURS (hrs)
0.18	100	100	10.7
0.20	91	91	11.7
0.25	73	73	14.7
0.30	61	61	17.6
0.35	52	52	20.5
0.40	45	45	23.5
0.50	36	36	29.4
0.60	30	30	35.2
0.65	28	28	38.2
0.70	26	26	41.1
0.75	24	24	44.0
0.80	23	23	47.0
0.85	21	21	49.9
0.90	20	20	52.8
1.00	18	18	58.7
1.10	17	17	64.6
1.20	15	15	70.4
1.30	14	14	76.3
1.40	13	13	82.2
1.50	12	12	88.1
1.6	11	11	93.9

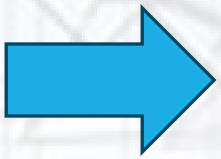
Use DIAL SETTING for correct depth

DATA IS WITH END GUN OFF

System FlowRate:	900.0	Flow Test?:	CHAC
Pressure ON TOP:	32.0	Irrigated Acreage:	117
Distance to Tower 8:	1238.3	Minimum Depth:	0.18
Effective Reach:	1271.7	Fastest Circle:	10.7
Static Water Level:	0.0	50 ft Time @100%:	4.1
Pumping Water Level:	0.0	20% Time:	12.00
System KW Demand:	0.0	50% Time:	30.00
Percent of Circle Irrig	100%	Cycle Time:	60.00

Provided by Cactus Hill Ag Consulting, LLC

Pressure Drop



John Smith XYZ

Irrigation Depth Chart

7-Jul-23

DEPTH (in)	TRUE PERCENT (%)	DIAL SETTING (%)	HOURS (hrs)
0.15	100	100	10.7
0.20	75	75	14.2
0.25	60	60	17.7
0.30	50	50	21.2
0.35	43	43	24.8
0.40	38	38	28.3
0.50	30	30	35.4
0.60	25	25	42.5
0.65	23	23	46.0
0.70	21	21	49.6
0.75	20	20	53.1
0.80	19	19	56.7
0.85	18	18	60.2
0.90	17	17	63.7
1.00	15	15	70.8
1.10	14	14	77.9
1.20	13	13	85.0
1.30	12	12	92.1
1.40	11	11	99.2
1.50	10	10	106.2
1.6	9	9	113.3

Use DIAL SETTING for correct depth

DATA IS WITH END GUN OFF

System FlowRate:	746.0	Flow Test?:	CHAC
Pressure ON TOP:	22.0	Irrigated Acreage:	117
Distance to Tower 8:	1238.3	Minimum Depth:	0.15
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Pumping Water Level:	0.0	20% Time:	12.00
System KW Demand:	0.0	50% Time:	30.00
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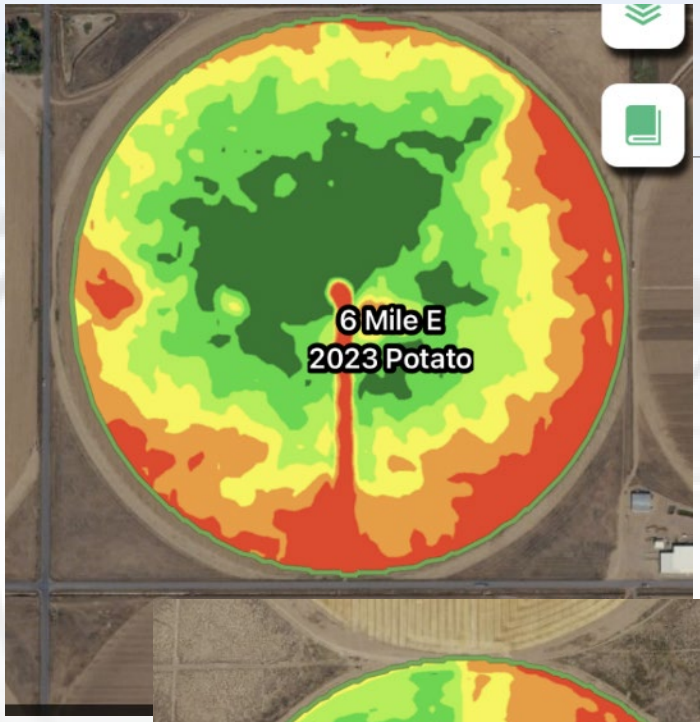
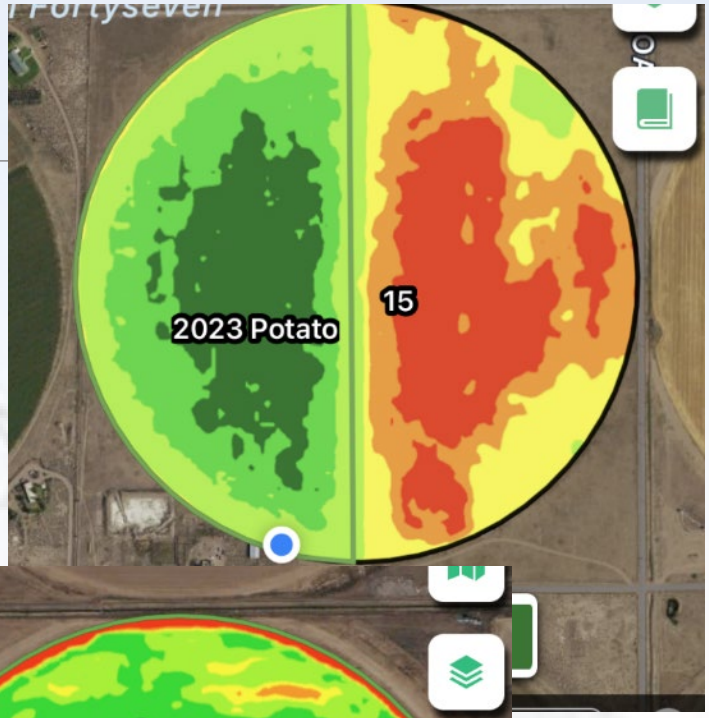
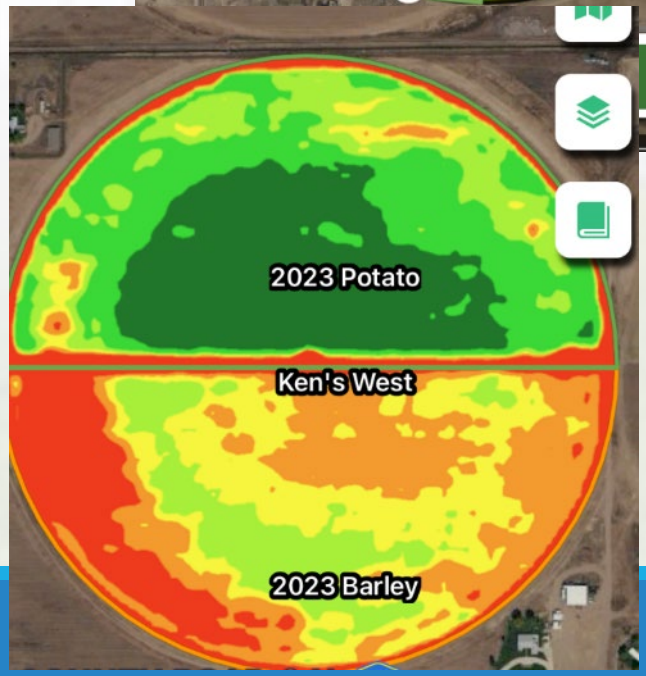
Effects of Low Pressure







John Smith XYZ

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0.35	52	52	20.5
0.40	45	45	23.5
0.50	36	36	29.4
0.60	30	30	35.2
0.65	28	28	38.2
0.70	26	26	41.1
0.75	24	24	44.0
0.80	23	23	47.0
0.85	21	21	49.9
0.90	20	20	52.8
1.00	18	18	58.7
1.10	17	17	64.6
1.20	15	15	70.4
1.30	14	14	76.3
1.40	13	13	82.2
1.50	12	12	88.1
1.6	11	11	93.9

Use DIAL SETTING for correct depth

DATA IS WITH END GUN OFF

System FlowRate:	900.0	Flow Test?:	CHAC
Pressure ON TOP:	32.0	Irrigated Acreage:	117
Distance to Tower 8:	1238.3	Minimum Depth:	0.18
Effective Reach:	1271.7	Fastest Circle:	10.7
Static Water Level:	0.0	50 ft Time @100%:	4.1
Pumping Water Level:	0.0	20% Time:	12.00
System KW Demand:	0.0	50% Time:	30.00
Percent of Circle Irrig	100%	Cycle Time:	60.00

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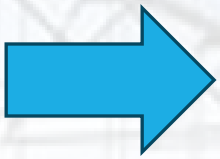
Change in Center Drive



John Smith XYZ

Irrigation Depth Chart

7-Jul-23

DEPTH (in)	TRUE PERCENT (%)	DIAL SETTING (%)	HOURS (hrs)
0.12	100	100	6.9
0.20	59	59	11.7
0.25	47	47	14.7
0.30	39	39	17.6
0.35	33	33	20.5
0.40	29	29	23.5
0.50	23	23	29.4
0.60	20	20	35.2
0.65	18	18	38.2
0.70	17	17	41.1
0.75	16	16	44.0
0.80	15	15	47.0
0.85	14	14	49.9
0.90	13	13	52.8
1.00	12	12	58.7
1.10	11	11	64.6
1.20	10	10	70.4
1.30	9	9	76.3
1.40	8	8	82.2
1.50	8	8	88.1
1.6	7	7	93.9

Use DIAL SETTING for correct depth

DATA IS WITH END GUN OFF

System FlowRate:	900.0	Flow Test?:	CHAC
Pressure ON TOP:	32.0	Irrigated Acreage:	117
Distance to Tower 8:	1238.3	Minimum Depth:	0.12
Effective Reach:	1271.7	Fastest Circle:	6.9
Static Water Level:	0.0	50 ft Time @100%:	2.7
Pumping Water Level:	0.0	20% Time:	12.00
System KW Demand:	0.0	50% Time:	30.00
Percent of Circle Irrig	100%	Cycle Time:	60.00

Provided by Cactus Hill Ag Consulting, LLC

Keep track of RAIN

Putting it all together: How do I **ACTUALLY** Schedule

What is my MAD? What irrigation depth will I use?

MAD = Root Depth X AWHC X Percent MAD

- **MAD / Irrigation Efficiency = Irrigation Depth**

How long since I last irrigated: in days

What is ET for those days

What is the rainfall over 0.1 inches

Calculate (and do a field check): **Deficit = ET x days – precip**

When I hit my MAD: Irrigate

Typical Irrigation depth (Sprinklers)

Alfalfa and irrigated pasture:

- New stand after planting: .4 inches
- Established stand:
  - 0.8 inches to 1.8 inches

Potatoes, soybeans, dry beans, peas and some vegetables:

- First irrigation or Pre-Water: Wet entire profile
- Rest of irrigations: .5 to 1.0 inches

Small grains and small seeded vegetables:

- Early: keep seed wet for germination, Break Crust, incorporate fertilizer
- Later: 0.5 to 1.2 depending on soil type

Putting it all together: EXAMPLE

What is my MAD? What irrigation depth will I use?

MAD= Root Depth X AWHC X Percent MAD

Example: Dry Beans at bloom in Montrose: 16 inches X 0.16 in/in X (40/100) = 1.02 inches

MAD / Irrigation Efficiency = Irrigation Depth

In the example: 1.02 inches/0.90 = 1.15

How long since I last irrigated in days: 4 days

What is ET for those days: 0.3, 0.3, 0.15, 0.24 = total of 0.99

What is the rainfall over 0.1 inches: Example = 0.2

Calculate (and do a field check): Deficit = ET x days – precip Example = (0.99 in 4 days) - 0.2 rain = 0.79 current deficit

When I hit my MAD: Irrigate

Deficit is 0.79 Currently, weather supposed to be windy and dry today so ET will likely be 0.3, MAD will be reached so start irrigation pm.

Keep track of your "Checkbook"

July Field	4 Mon	5 Tues	6 Weds	7 Thurs	8 Fri	9 Sat	10 Sun	11 Mon	12 Tues	13 Weds
GV1 Wheat W/Barley+Peas		0.8 am FM	0.8 pm Wh		0.8 am FM	0.8 pm Wh		0.8 am FM	0.8 pm Wh	
GV2 Wheat W/Barley+Peas		0.8 pm FM	0.8 pm Wh		0.8 pm FM	0.8 pm Wh		0.8 pm FM	0.8 pm Wh	
R1 Org Alfalfa		1.0 am				1.2 am				1.2 am
31 Canola	0.8 am			0.8 am			0.8 am			0.8 am
32		1.0 am				1.0 am				1.0 am
33 Alfalfa Org Trans		1.0 am				1.2 am				1.2 am
34 Alfalfa		1.0 am				1.2 am				1.2 am
35 Barley	0.8 am			0.7 am			0.7 am			0.7 am
37 Alfalfa/IRG		1.0 am				1.2 am				1.2 am
38 Barley	0.7 am to S			0.7 am to N			0.7 am to S			0.7 am to N
Carlson Canola			final N? 20? 0.8 pm			0.8 pm			0.8 pm	
RL 1 Pasture Grass?	1.0 am			1.0 pm				1.0 am		
RL 2 Pasture Grass?			1.0 am			1.0 pm				1.0 am

On the fly adjustments

1. MEMORIZE THIS!!!

$$Q_{(GPM)} T_{(hrs)} = 453\ A_{(acres)}\ D_{(In.)}$$

This is the basis for all percent charts

2. Adjusting for Pressure change:

$$\sqrt{\frac{Pressure\ New}{\div\ Old}} * \text{Old Flow (GPM)} = \text{APPROX NEW FLOW}$$

The Math

$\sqrt{Pressure\ New \div Old}$ * Old Flow (GPM) = APPROX NEW FLOW

$Q_{(GPM)} T_{(HRS)} = 453\ A_{(ACRES)}\ D_{(IN.)}$

1. ADJUST FLOW

$22 \div 32 = 0.875$

$\sqrt{0.6875 = 0.83}$

0.83 X 900 = 746 GPM

2. Adjust irrigation depth

You need to apply 0.7”

T (hrs)= (453 X A X D) ÷ Q

T (hrs)= (453 x 117 x 0.7) ÷ 746

T = 49.7 Hrs

3. ADJUST PERCENT TIMER:

Cheat and look up the time on the old chart, 21% **Or**

Adjust your 100% depth using the above Equation:

D=Q X T/ 453 X A D= (746 X 10.7) ÷ 453 X 117 D=0.15

% SETTING = 0.15/0.7 X 100 = 21%


Questions?

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